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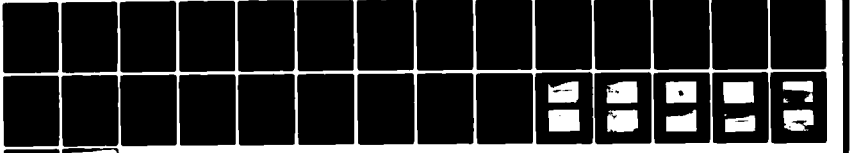

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dam Safety, Lake, Dam Inspection, Private Dams

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

FRONTIER LAKE DAM
WAYNE COUNTY, MISSOURI

MISSOURI INVENTORY NO. 30007

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

PREPARED BY: ST. LOUIS DISTRICT CORPS OF ENGINEERS
FOR: GOVERNOR OF MISSOURI

AUGUST 1973

PHASE I REPORT

NATIONAL DAM SAFETY PROGRAM

Name of Dam	Frontier Lake Dam
State Located	Missouri
County Located	Wayne County
Stream	Camp Creek
Date of Inspection	12 July 1978

Frontier Lake Dam was inspected by an interdisciplinary team of engineers from the Memphis District, U.S. Army Corps of Engineers. The purpose of the inspection was to make an assessment of the general condition of the dam with respect to safety, based upon available data and visual inspection, in order to determine if the dam poses hazards to human life or property.

The guidelines used in the assessment were furnished by the Department of the Army, Office of the Chief of Engineers and developed with the help of several Federal and State agencies, professional engineering organizations, and private engineers. Based on these guidelines, this dam is classified as a intermediate size dam with a high downstream hazard potential. Failure would threaten the life and property fo approximately 6 families downstream of the dam and cause appreciable damage to highway N, approximately 1 1/4 miles downstream of the dam.

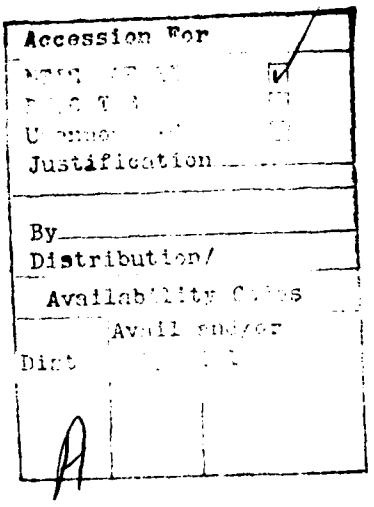
The inspection and evaluation indicate that the spillway does not meet the criteria set forth in the guidelines for a dam having the above mentioned size classification and hazard potential. According to the guidelines, the spillway is required to pass the Probable Maximum Flood (PMF) without the dam embankment being overtopped. The spillway will only pass 15 percent of the PMF before the dam embankment is overtopped. Because the spillway will not pass 1/2 of the PMF without overtopping, the dam is classified as "unsafe non-emergency." Also the spillway will not pass the 100-year flood without overtopping, which is a flood that has a 1 percent chance of being exceeded in any given year.

Other deficiencies visually observed by the inspection team were bushes and small trees on the downstream embankment slope, no erosion protection on the upstream embankment slope and no erosion protection on the emergency spillway guide dike near the spillway outfall. Another deficiency found was the lack of seepage and stability analysis records.

It is recommended that the owner take action to correct or control the deficiencies described. Corrective works should be in accordance with analyses and design performed by an engineer experienced in the design and construction of dams.

Jerry L. Anderson

JERRY L. ANDERSON
Hydraulic Engineer
Memphis District
Corps of Engineers



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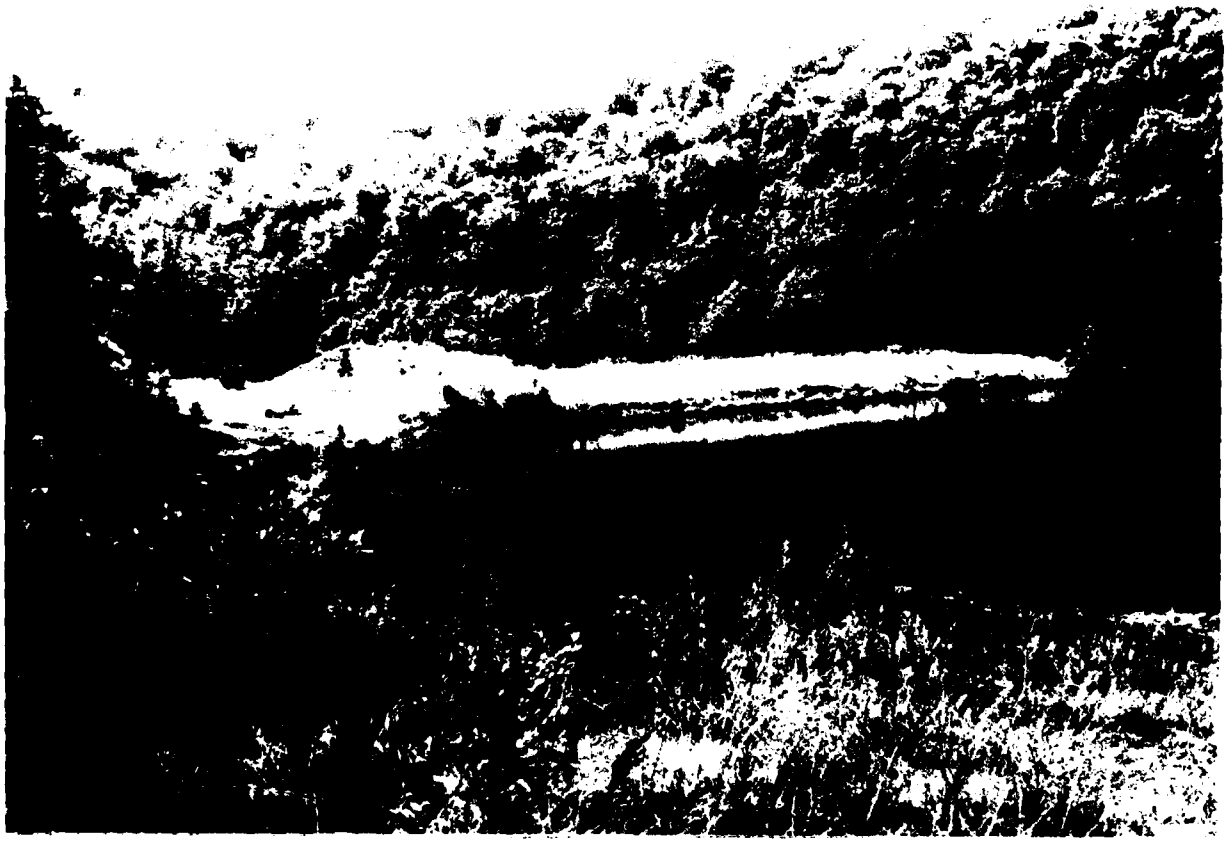
Corps of Engineers

SUBMITTED BY: SIGNED — 22 SEP 1970
Chief, Engineering Division — Date

APPROVED BY: SIGNED — 22 SEP 1970
Colonel, CE, District Engineer — Date



Ocean Lake and Pier

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
FRONTIER LAKE DAM - ID NO. 30007

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SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority. The National Dam Inspection Act, Public Law 92-367, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a program of safety inspection of dams throughout the United States. Pursuant to the above, the St. Louis District, Corps of Engineers, District Engineer directed that a safety inspection of the Frontier Lake Dam be made.

b. Purpose of Inspection. The purpose of the inspection was to make an assessment of the general condition of the dam with respect to safety, based upon available data and visual inspection, in order to determine if the dam poses hazards to human life or property.

c. Evaluation Criteria. Criteria used to evaluate the dam were furnished by the Department of the Army, Office of the Chief of Engineers, in "Recommended Guidelines for Safety Inspection of Dams." These guidelines were developed with the help of several Federal agencies and many State agencies, professional engineering organizations, and private engineers.

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances.

(1) The dam is an earth structure built in a narrow valley in the uplands which border the Mississippi Embayment. Topography adjacent to the valley is rolling to steep. Soils in the area are formed of sandy clays with rock fragments. Topography in the vicinity of the dam is shown on Plate 2.

(2) A vertical inlet constructed of 42-inch diameter, smooth iron pipe junctioned with a 30-inch smooth iron pipe is the primary means of discharge. A valve controlled lake drain consisting of an 18-inch diameter pipe is also connected to the 42-inch inlet pipe. An emergency spillway is cut into rock on the left abutment. The spillway is a trapezoidal section with a 55-foot bottom width and side slopes of approximately 1V on 3H. The spillway is 120 feet long from the crest of the spillway.

(3) Pertinent physical data are given in paragraph 1.3 below.

b. Location. The dam is located in the central portion of Wayne County, Missouri, as shown on Plate 1. The lake formed by the dam is shown on the Patterson, Missouri Quadrangle sheet in Sections 26, 27, 34, and 35; Township 30 North; Range 4 East.

c. Size Classification. Criteria for determining the size classification of dams and impoundments are presented in the guidelines referenced in paragraph 1.1 c above. Based on these criteria, this dam and impoundments is in the intermediate size category.

d. Hazard Classification. Guidelines for determining hazard classification are presented in the same guidelines as referenced in paragraph c above. Based on referenced guidelines, this dam is in the High Hazard Classification.

e. Ownership. This dam is owned by Mrs. Diana Ward of Frontier Lake, Patterson, Missouri 63956.

f. Purpose of Dam. The dam forms a 62-acre recreational lake.

g. Design and Construction History. The dam was designed by the U.S. Department of Agriculture Soil Conservation Service. Readily available design data were limited to a set of drawings dated August 1964. The drawings consist of a hydraulic and hydrologic design, a location plan, a typical embankment cross-section (see Plate 5) and a section through dam centerline (see Plate 4). Whether or not slope stability and seepage analyses were performed using suitable loading condition is unknown. A contractor from Poplar Bluff, Missouri constructed the dam during 1965. Location of borrow areas and the effort utilized in compacting the borrow material is unknown. A core trench was reportedly placed beneath the embankment. A typical embankment cross-section from the 1964 drawings showing the primary features of the vertical inlet and discharge system is presented on Plate 5. Based on the inspection survey, an average 1V on 2.2H downstream embankment slope was used instead of 1V on 2H slope specified in the 1964 drawings and an average 1V on 3.3H upstream embankment slope was used instead of the specified 1V on 3H.

h. Normal Operating Procedure. Normal rainfall, runoff, transpiration, and evaporation all combine to maintain a relatively stable water surface elevation. The emergency spillway was reportedly used several times with the maximum experienced depth of approximately one half of a foot occuring in March 1977. A lake drain is provided to draw down the lake level during the winter months for biological lake maintenance.

1.3 PERTINENT DATA

a. Drainage Area - 3350 acres (1973 inventory).
3287 acres (1964 drawings).
3206 acres (Topographic Quadrangle).

b. Discharge at Damsite.

(1) Discharge can take place both through a vertical pipe inlet and an emergency spillway.

(2) Estimated experienced maximum flood at the damsite - 180 cfs.

c. Elevation (Feet above M.S.L.)

(1) Top of dam - 671.5 ± (Existing, see Plate 4).
669.6 ± (1964 Design, see Plate 4).

(2) Top of vertical inlet - 661.9.

(3) Invert of discharge pipe at the stilling basin - 651.7.

(4) Spillway crest - 667.0 ± (Existing).
666.3 ± (1964 Design).

(5) Streambed at centerline of dam - 651.5 (1964 drawings).

(6) Maximum tailwater - unknown.

d. Reservoir. Length of maximum pool - 3700 ± feet (1964 drawings).

e. Storage (Acre-feet).

(1) Maximum - 992 (1973 inventory).
1638 (1964 drawings and 843 acre-feet as normal storage).

(2) Normal - 843 (1973 inventory).

f. Reservoir Surface (Acres).

(1) Top of dam - 102.5.

(2) Spillway crest - 83.4

(3) Invert of vertical inlet - 62.3.

g. Dam.

(1) Type - earth embankment.

(2) Length - 375 ± feet.

(3) Height - 40 feet maximum.

(4) Top width - 13 ± feet.

(5) Side slopes -

(a) Downstream - 1V on 2.2H (Average).

(b) Upstream - 1V on 3.3H (Average).

(6) Downstream berm - el. 654 ± feet m.s.l. and 8 feet wide (All Average existing conditions.)

(7) Upstream berm - dimensions no longer definable.

(8) Zoning - unknown.

(9) Impervious core - unknown.

(10) Cutoff - Reportedly placed beneath embankment.

(11) Grout curtain - unknown.

h. Diversion and Regulating Tunnel. None.

i Primary Discharge System.

(1) Type - An uncontrolled 42-inch diameter inlet pipe junctioned with a 30-inch diameter discharge pipe (see paragraph 1.2 a).

(2) Length of 42-inch diameter pipe - 16 feet (1964 drawings).

(3) Length of 30-inch diameter pipe - 146 feet (1964 drawings).

(4) Top elevation of vertical inlet - 661.9 feet m.s.l.

(5) Invert of discharge pipe at stilling basin - 631.7 feet m.s.l.

j. Emergency Spillway.

(1) Type - Uncontrolled (rock).

(2) Width of weir - 55 feet (Bottom width).

(3) Length of weir - 120 ± feet (From crest of Spillway).

(4) Crest elevation - 667.0 ± feet m.s.l.

k. Regulating Outlet.

(1) Type - valve controlled 18-inch diameter pipe.

(2) Pipe Length - 30 feet (Estimate).

(3) Invert of pipe in lake - unknown.

(4) Discharge Invert - 655.0 feet m.s.l. (Discharges into 42-inch diameter inlet pipe).

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

The dam was designed by the U.S. Department of Agriculture Soil Conservation Service. Readily available design data were limited to a set of drawings dated August 1964. The drawings consist of a hydraulic and hydrologic design, a location plan, a typical embankment cross-section (see Plate 5), and a center-line section through the dam (see Plate 4). Whether or not slope stability and seepage analyses were performed using suitable loading conditions is unknown.

2.2 CONSTRUCTION

The dam was constructed in 1965 by a construction company from Poplar Bluff, Missouri. The earth embankment was probably constructed of a red sandy clay with varying amounts of rock fragments. The location of the borrow areas and the effort utilized in compacting the borrow material is unknown. A core trench was reportedly placed below the embankment. A typical embankment cross-section from the 1964 drawings showing the primary features of the vertical inlet and discharge system is presented on Plate 5. Based on the inspection survey an average 1V on 2.2H downstream embankment slope was used instead of the 1V on 2H slope specified in the 1964 drawings and an average 1V on 3.3H upstream embankment slope was used instead of the specified 1V on 3H.

2.3 OPERATION

The emergency spillway was reportedly used several times when the vertical inlet pipe became obstructed. The emergency spillway was reportedly used only once when the inlet pipe was not obstructed. This occurred in March 1977 when the emergency spillway flow was approximately 0.5 feet deep (see Photos 8, 9, 10, and 11).

2.4 EVALUATION

a. Availability. The only engineering data available were mentioned in paragraphs 2.1 - 2.3 above.

b. Adequacy. The 1964 hydraulic and hydrologic design was inadequate to assess if the dam could pass the probable maximum flood (PMF) without overtopping. The design presented on the 1964 drawing was for a 50-year frequency storm which is much smaller than the PMF.

Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record.

c. Validity. The engineering data presented appeared to be valid.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General. Visual inspection of Frontier Lake Dam was performed on 12 July 1978. Personnel making the inspection were employees of the Memphis District, Corps of Engineers, and included a geologist, hydraulic engineer, and soils engineer. Specific observations are discussed below.

b. Project Geology. The dam is located on the uplands which border the Mississippi Embayment and lies on the Pre-Cambrian granite bedrock. In this area the rock is a red and gray granite with granite porphyries. Outcrops of the granite occur in both abutments and boulders and outcrops are exposed in the spillway area. Based on the soil types in the area and exposed soils in the embankment, the dam is probably composed of sandy clay with rock fragments. The dam is located in Seismic Zone 2.

c. Dam. No detrimental settlement, cracking, slides or animal burrows were observed in or near the earth embankment. Typical existing cross-sections of the embankment are shown on Plates 6, 7, and 8. These sections are consistent with the cross-section presented in the Soil Conservation Service 1964 drawings (see Plate 5). Vertical erosion faces 2-3 feet high, were observed along the upstream embankment slope (see Photo 2). Several 5 to 8-foot high bushes and trees were growing on the downstream slope (see Photo 3).

d. Appurtenant Structures. A vertical inlet constructed of 42-inch diameter, smooth iron pipe junctioned with a 30-inch diameter, smooth iron pipe is the primary means of discharge. A metal baffle is mounted on the vertical inlet. A trash rack consisting of a welded cage of reinforcement rods surrounds the inlet (see Photo 4). The outlet pipe discharges into a stilling basin protected with a thick riprap blanket (see Photo 5).

An emergency spillway on the left abutment is cut into rock consisting primarily of granite. The spillway is a trapezoidal section with a 55-foot bottom width and side slopes of approximately 1V on 3H. The spillway is 120 feet long from the crest of the spillway (see Photo 6).

The spillway is paralleled by a guide dike or berm which diverts the spillway outfall from the dam embankment (see Plate 3). The end of the spillway guide dike has been eroded toward the dam embankment

by flow through the emergency spillway (see Photo 7). Water flowing through the emergency spillway outfall and attacking the spillway guide dike is shown on Photos 9, 10, and 11 which were taken by the Soil Conservation Service in March 1977. The emergency spillway was flowing at an approximate depth of 0.5 feet.

A valve controlled lake drain consisting of an 18-inch diameter pipe is junctioned to the 42-inch diameter vertical inlet pipe (see Plate 7). Because of the unaccessible location of the drain, it could not be inspected. Reportedly the lake is drawn down several feet every winter for biological lake maintenance.

e. Reservoir Area. No excessive erosion or slides were observed along the shore of the reservoir. But wave wash has eroded a 2-3 foot vertical face along the shore.

f. Downstream Channel. The downstream channel is not overgrown with vegetation and is protected with a rock blanket.

3.2 EVALUATION

None of the conditions observed are significant enough to indicate a need for immediate remedial action or a serious potential of failure. Erosion on the upstream embankment slope and on the emergency spillway guide dike, and vegetation on the downstream slope are deficiencies which, left uncontrolled or uncorrected, could lead to the development of potential problems.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

The primary discharge system and the emergency spillway are uncontrolled; therefore, no regulating procedures exist for these structures. The valve controlled lake drain described in paragraph 3.1 d is used for biological lake maintenance. Reportedly the lake is drawn down several feet every winter.

4.2 MAINTENANCE OF DAM

The dam embankment and appurtenant structures appear well maintained, except for the erosion on the upstream embankment slope and on the emergency spillway guide dikes, and the bushes and small trees on the downstream slope.

4.3 MAINTENANCE OF OPERATING FACILITIES

No information is available concerning maintenance of the lake drain.

4.4 DESCRIPTION OF ANY WARNING SYSTEM IN EFFECT

The inspection team is not aware of any existing warning system for this dam.

4.5 EVALUATION

If the erosion on the upstream embankment slope and on the emergency spillway guide dikes, and the tree and brush growth on the downstream embankment slope are allowed to continue, a serious potential of failure may develope.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

a. Design Data. The available hydraulic and hydrological design appears accurate and is discussed in SECTION 2.

b. Experience Data. The drainage area was developed using USGS Patterson Quadrangle. The lake surface area and storage values were determined using the 1964 drawings furnished by the Soil Conservation Service. The spillway and dam layout are made from surveys conducted by the inspecting team. Comparisons were made with the 1964 drawings and the inspection surveys. All relative elevations are compatable with the elevations on the 1964 drawings.

c. Visual Observations.

(1) The vertical shaft and rock spillway are in excellent condition.

(2) The vertical shaft is located approximately 163 feet from the right abutment while the spillway is located in the left abutment. Releases from either structure will not endanger the integrity of the dam.

d. Overtopping Potential. The spillway will pass 15 percent of the Probable Maximum Flood (PMF), without overtopping the dam. The Probable Maximum Flood (PMF) is defined as the flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. For its size and hazard category, this dam is required by the guidelines to pass the PMF. Because the spillway will not pass one-half of the PMF without overtopping, the dam is classified as "unsafe non-emergency." The spillway will not pass the 100-year flood without overtopping, which is a flood that has a one percent chance of being exceeded in any given year.

The effect from rupture of the dam could extend approximately 10 miles downstream of the dam. There are 5 inhabited homes downstream of the dam which could be severly damaged and lives of the inhabitants could be lost, should failure of the dam occur.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

a. Visual Observations. Visual observations of the dam and appurtenant structures are discussed and evaluated in SECTIONS 3 and 5.

b. Design and Construction Data. The design and construction data were limited to that information discussed in SECTION 2.

c. Operating Records. There have been no known operations which have affected the structural stability of the dam.

d. Post Construction Changes. No post construction changes exist which will affect the structural stability of the dam.

e. Seismic Stability. This dam is located in Seismic Zone 2. However, it is located very near the boundary between Seismic Zones 2 and 3. Since this dam is located in Seismic Zone 2 and the proximity of Seismic Zone 3, it is possible that an earthquake could occur of sufficient intensity to cause severe damage or failure of the dam.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety. Several items were noted during the visual inspection by the inspection team which should be corrected or controlled. These items are erosion on the upstream embankment slope and on the emergency spillway guide dike, and brush and small trees on the downstream embankment slope. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety inspection of Dams" were not available which is considered a deficiency. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record. Also these analyses should be utilized to detail the corrective actions called for in paragraph 7.2. The probable maximum design flood (PMF) and 1/2 PMF will overtop the dam.

b. Adequacy of Information. Due to the lack of applicable engineering design and construction data, the conclusions in this report were based on performance history and external visual conditions. The inspection team considers that these data are sufficient to support the conclusions herein.

c. Urgency. The remedial measures recommended in paragraph 7.2 should be accomplished in the near future. If the deficiencies listed in paragraph 7.1a are not corrected in a timely manner, they could lead to the development of potential problems.

d. Necessity for Phase II. Based on the results of the Phase I inspection, no Phase II inspection is recommended.

e. Seismic Stability. This dam is located in Seismic Zone 2. However, it is located very near the boundary between Seismic Zones 2 and 3. Since this dam is located in Seismic Zone 2 and the proximity of Seismic Zone 3, it is possible that an earthquake could occur of sufficient intensity to cause severe damage or failure of the dam.

7.2 REMEDIAL MEASURES

a. Alternatives. Spillway size and/or height of dam should be increased to pass the Probable Maximum Flood without overtopping the dam.

b. Perform seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams." These seepage and stability analyses should be performed

for appropriate loading conditions (including earthquake loads) and made a matter of record. Use the results of these analyses to design appropriate corrective measures.

c. O & M Maintenance and Procedures. The following O & M maintenace and procedures are recommended:

(1) Remove the bushes and trees growing on the downstream slope. Care should be taken during removal not to destroy the existing condition of the downstream slope.

(2) Protect the upstream embankment slope with an adequate riprap blanket to prevent wave wash erosion.

(3) Protect the emergency spillway guide dike near the spillway outfall with an adequate riprap blanket to prevent erosion caused by water flowing through the emergency spillway outfall.

(4) A detailed inspection of the dam should be made at least every 5 years by an engineer experienced in design and construction of dams.

APPENDIX A

HYDROLOGIC COMPUTATIONS

HYDROLOGIC COMPUTATIONS

1. HEC-1 was used to develop the inflow hydrograph for PMF and hydrologic characteristic of drainage basin.

2. HEC-1 uses **Snyder** Method for developing synthetic unit hydrographs with Clarks Modification.

Final Variables

Drainage Area	5.01 sq. mi.
Travel Time of Runoff	1.26 hr.
Initial Loss of Rainfall	0.5 in.
Average Loss Rate	0.05 in./hr.
C_t	0.81
C_p	0.604
PMF Rainfall	**26.7 in.**
PMF Percentages	**6 hr. 102**
	12 hr. 120
	24 hr. 130

3. The inflow hydrograph was routed through the reservoir using HEC-1's modified Puls option. Releases were calculated for both the pipe and spillway. The pipe was assumed flowing full and the broadcrested weir equation was used to calculate spillway discharges. Variables for the pipe and spillway discharges are listed below.

Horizontal Pipe		**Vertical Pipe**	
n	**.013**	**n**	**.013**
L	**146 ft.**	**L**	**16 ft.**
D	**2.5 ft.**	**D**	**3.5 ft.**

Spillway

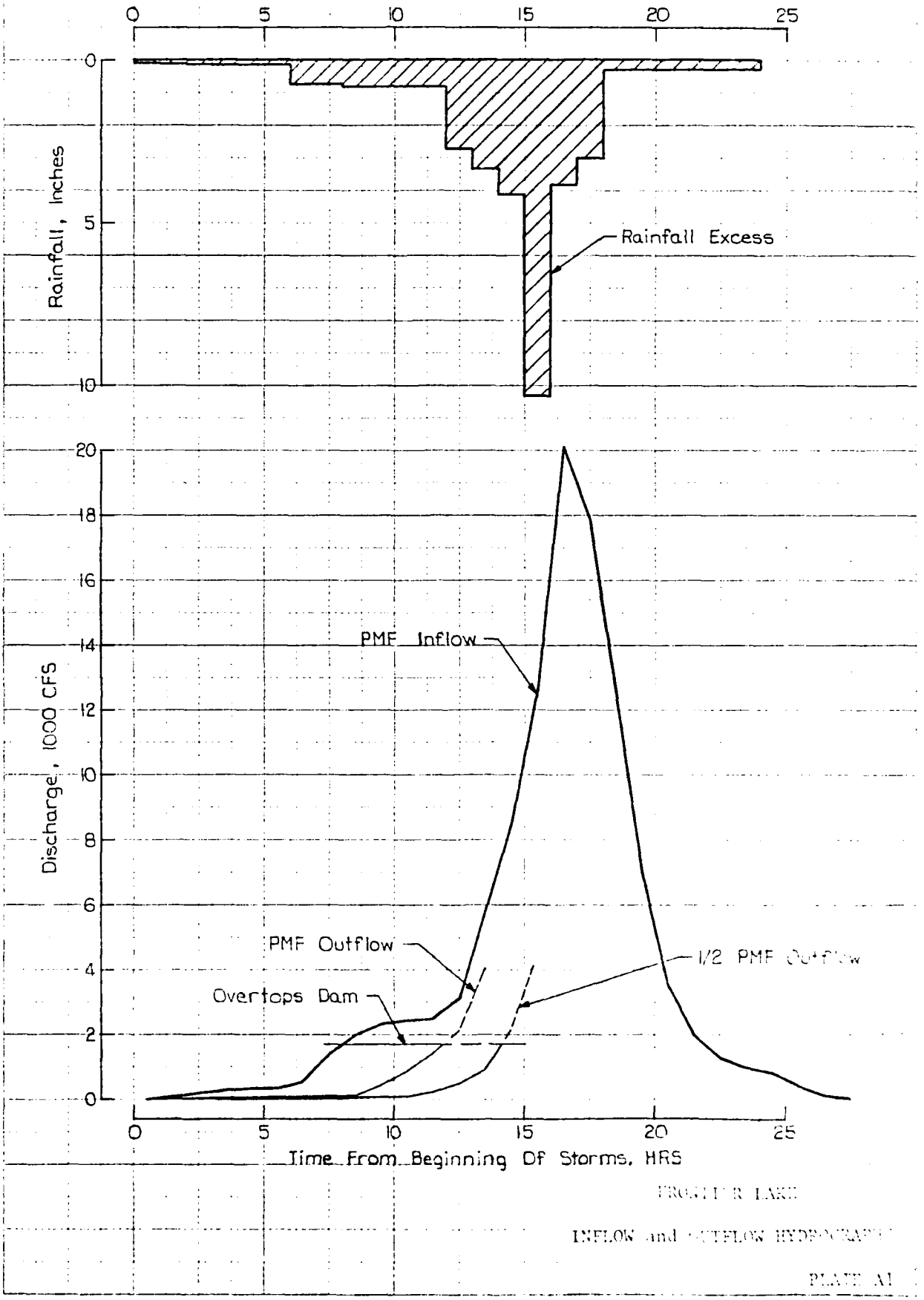
C	2.8
L	55 ft. *

* Used actual area of cross section at depth under consideration.

Top of Dam

C	2.5
L	300 ft.

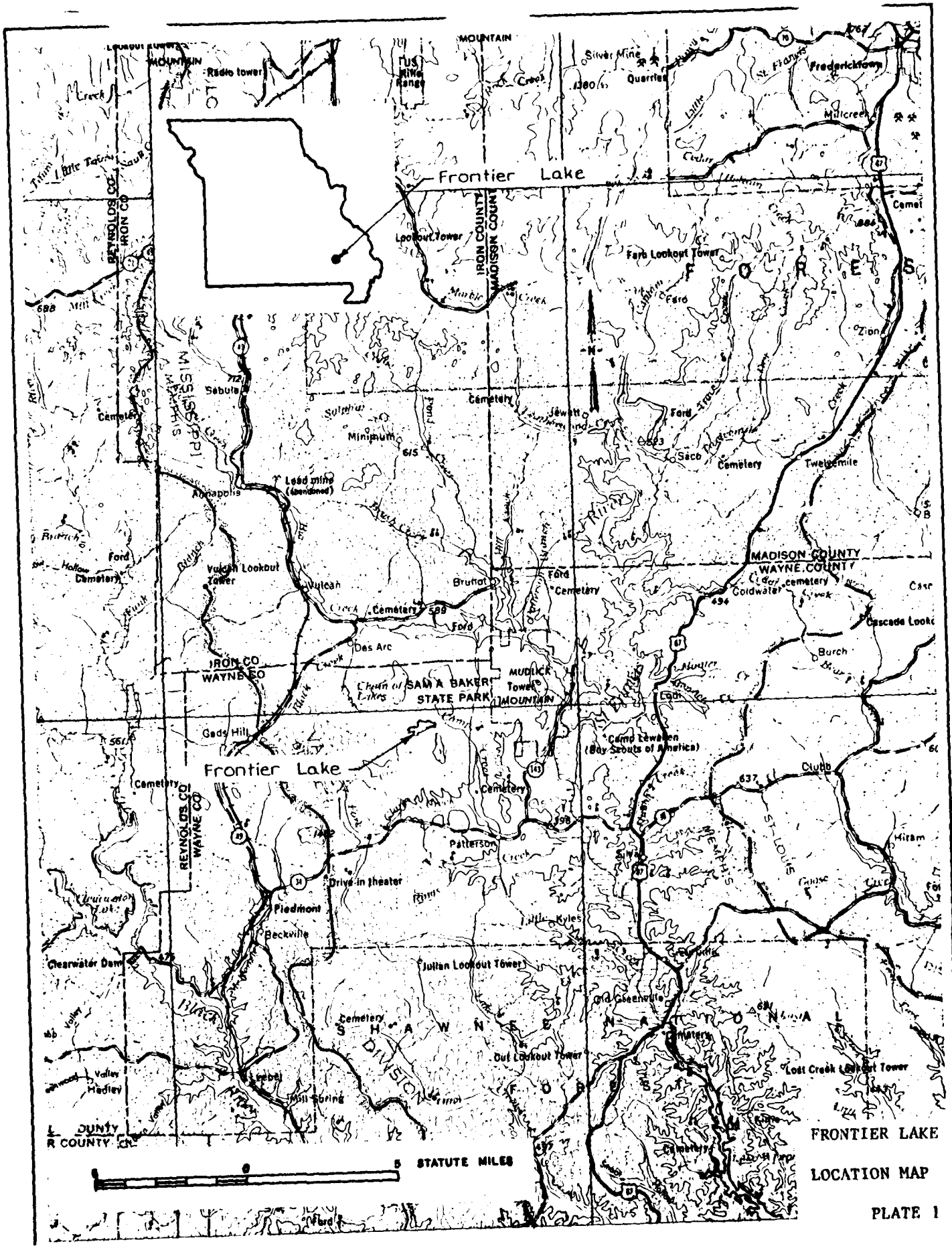
4. PMF rainfall distribution, inflow hydrograph, and outflow hydrograph are shown on Plate A1.



FROSTY R LAKE

INFLOW and OUTFLOW HYDROGRAPH

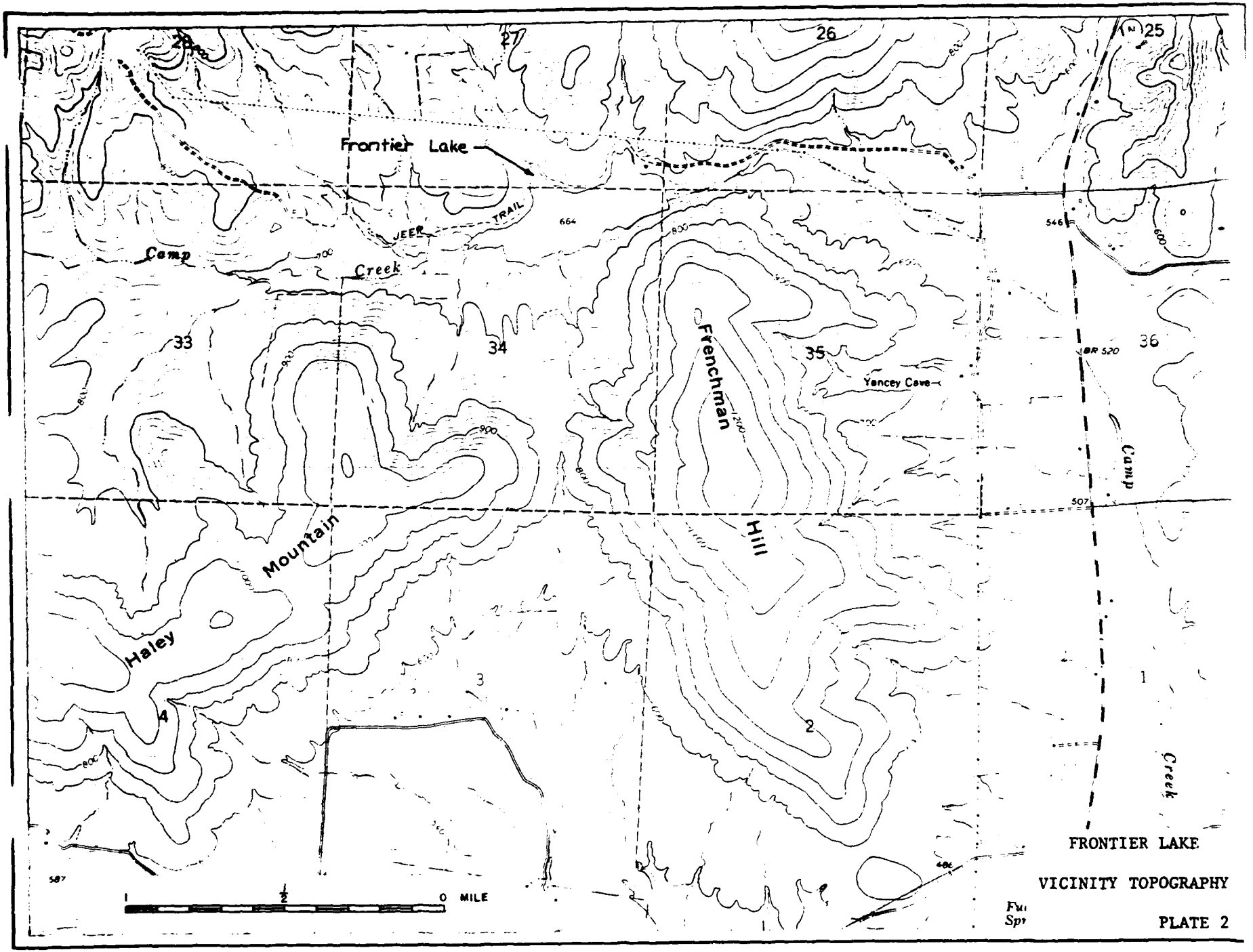
PLATE A1



FRONTIER LAKE

LOCATION MAP

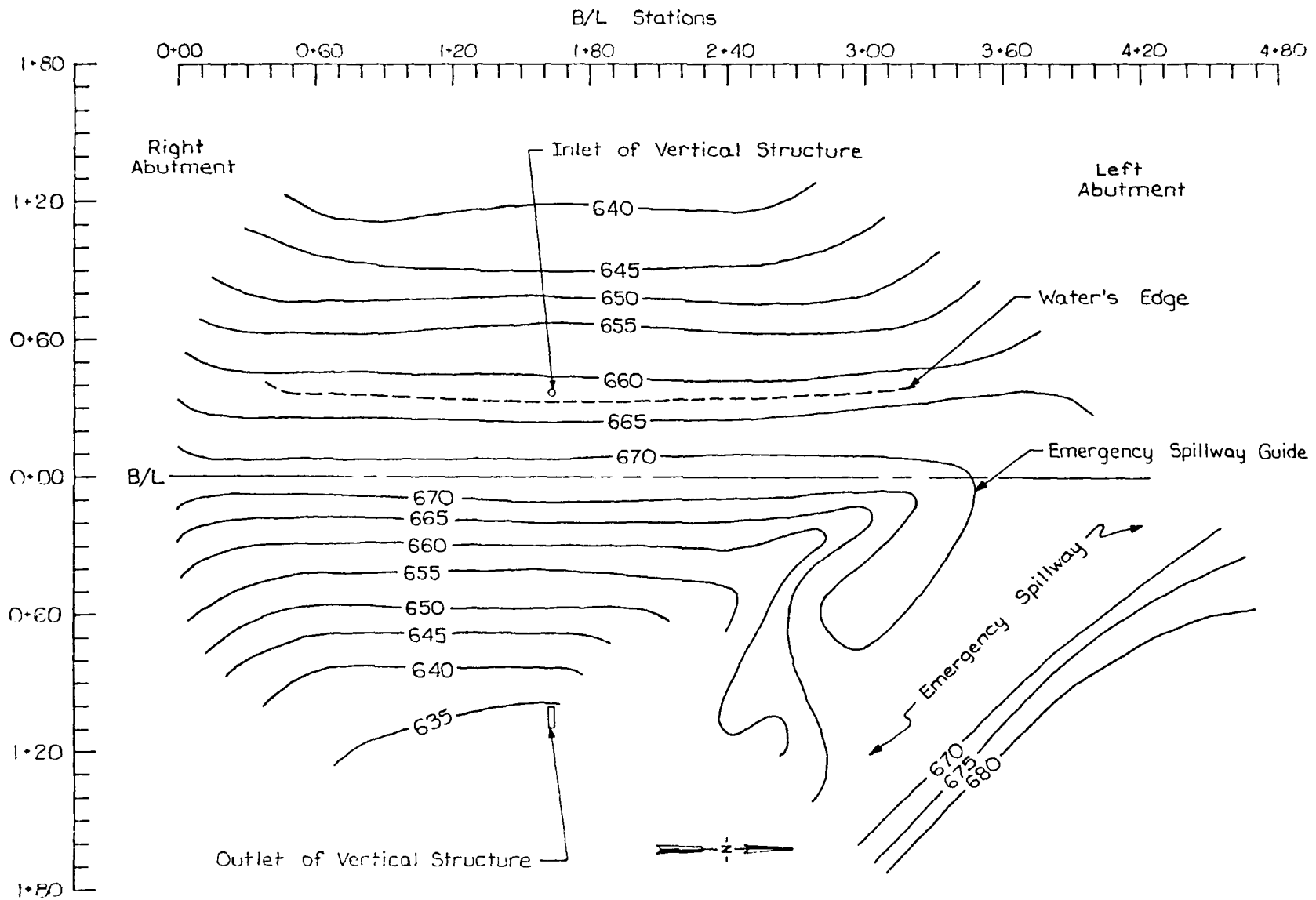
PLATE 1



FRONTIER LAKE

VICINITY TOPOGRAPHY

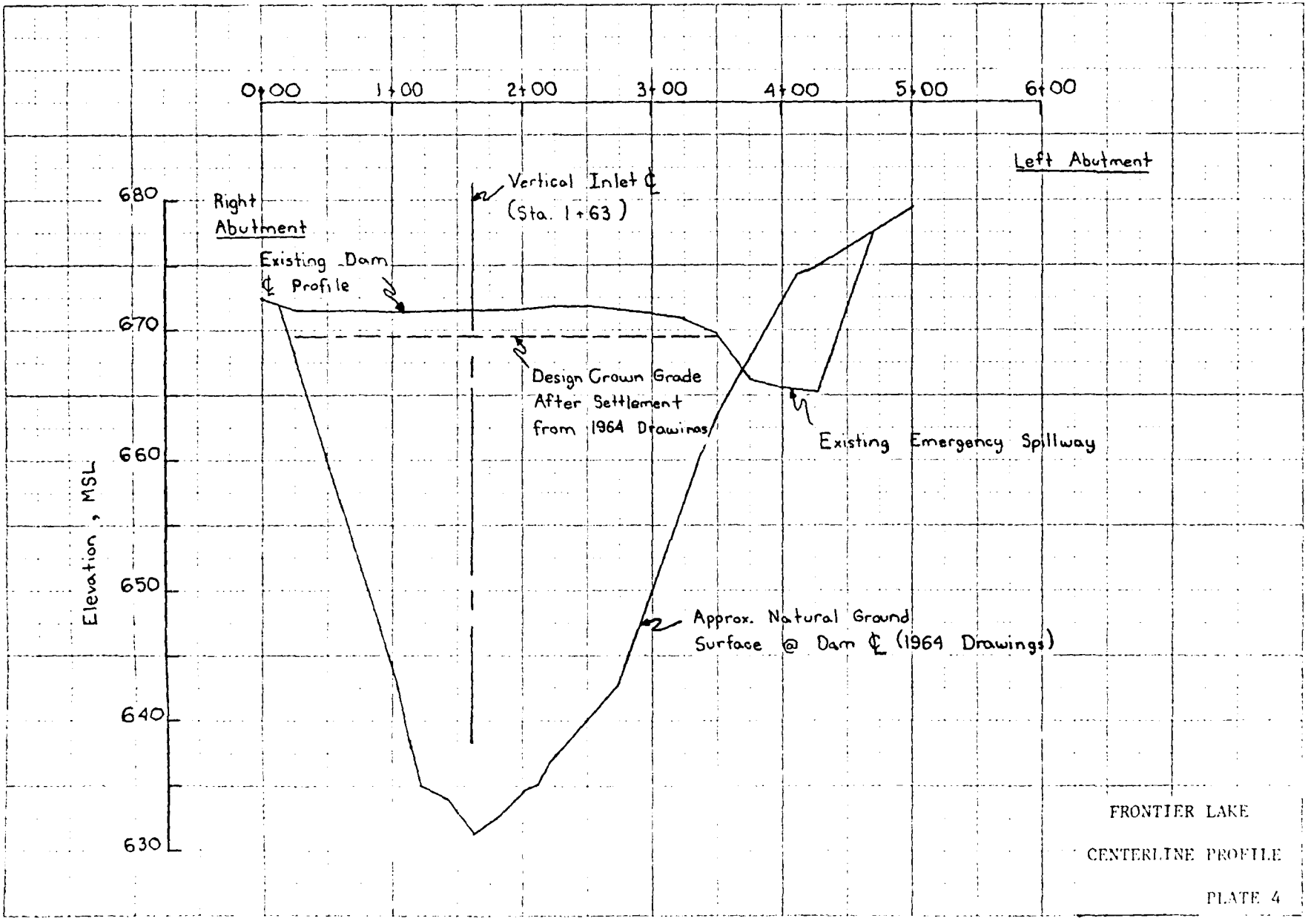
PLATE 2



FRONTIER LAKE

DAM PLAN VIEW

PLATE 3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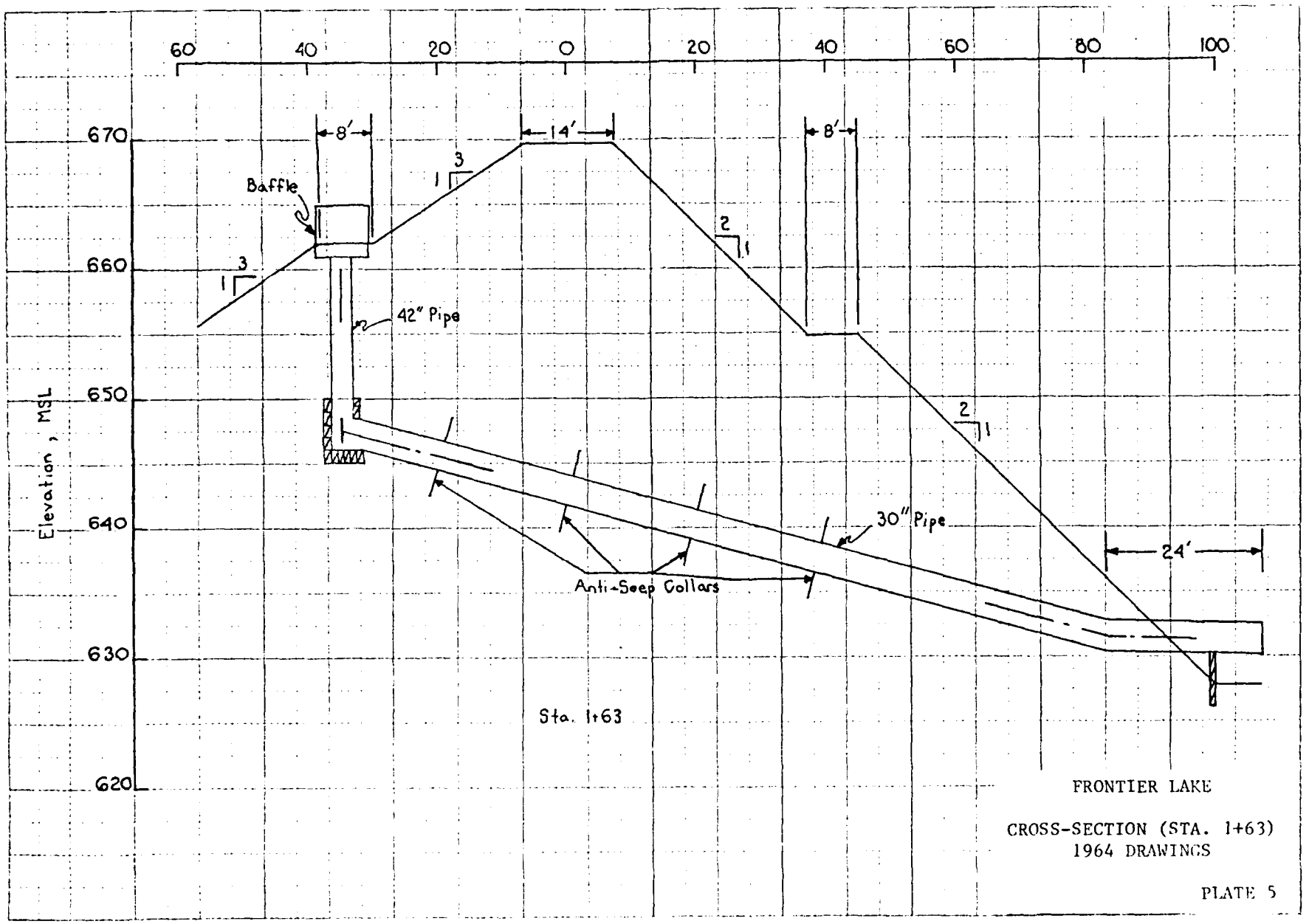
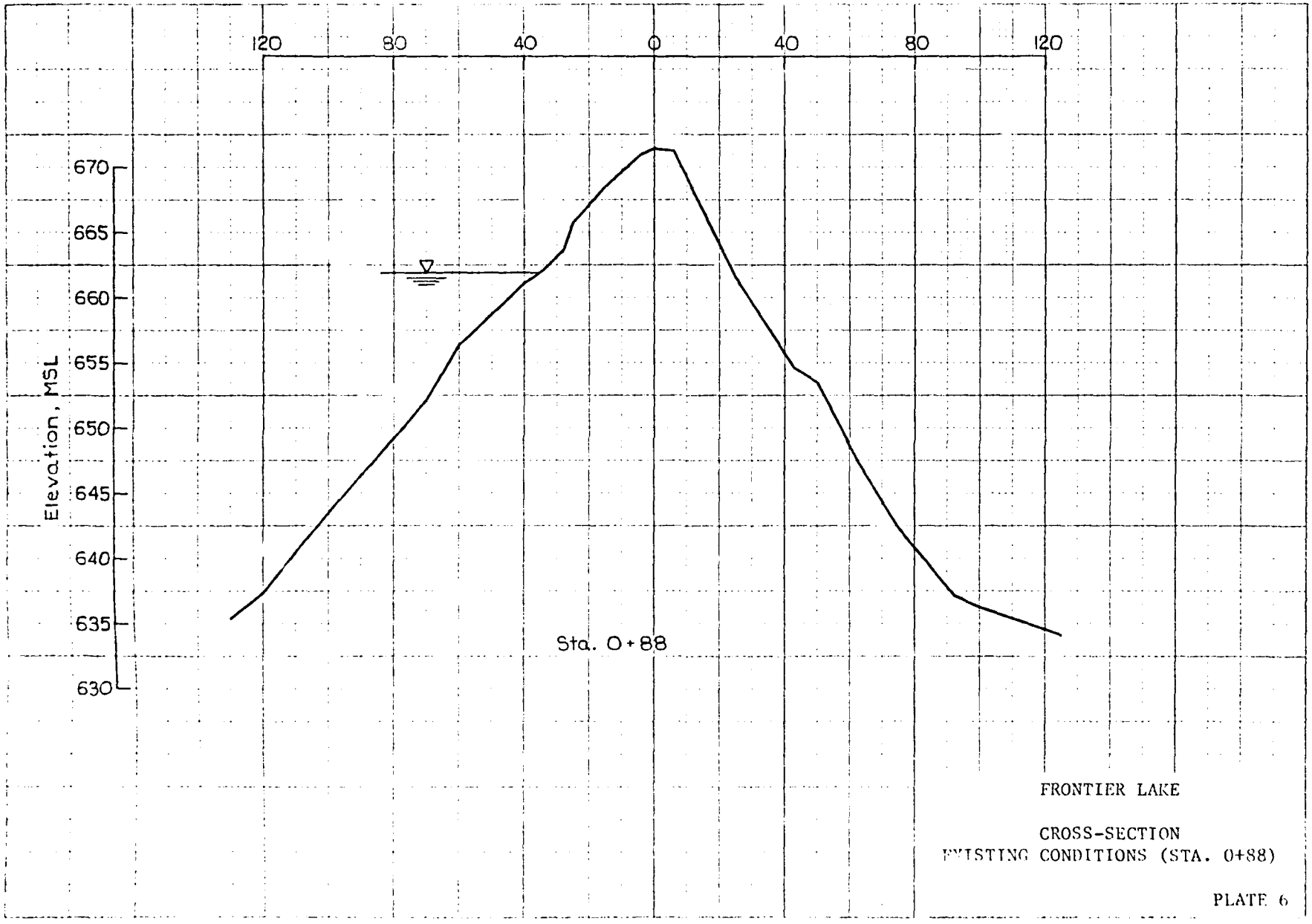
1+00
2+00
3+00
4+00
5+00
6+00
Left Abutment
Vertical Inlet ℄
(Sta. 1+63)
680
Right
Abutment
Existing Dam
℄ Profile
670
Design Crown Grade
After Settlement
from 1964 Drawings
660
Existing Emergency Spillway
Elevation, MSL
650
Approx. Natural Ground
Surface @ Dam ℄ (1964 Drawings)
640
630
FRONTIER LAKE
CENTERLINE PROFILE
PLATE 4



FRONTIER LAKE

CROSS-SECTION (STA. 1+63)
1964 DRAWINGS

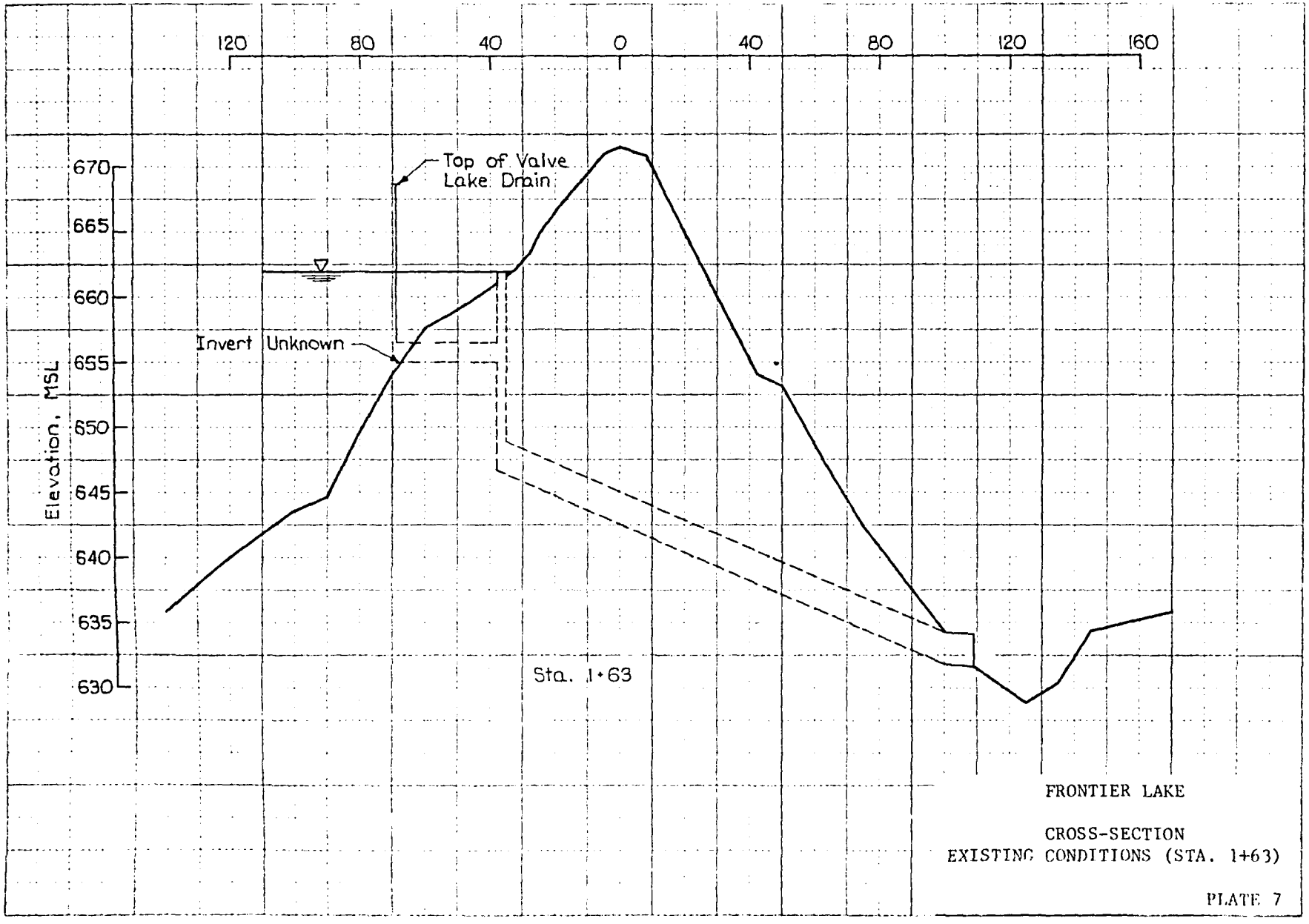
PLATE 5



FRONTIER LAKE

CROSS-SECTION
EXISTING CONDITIONS (STA. 0+88)

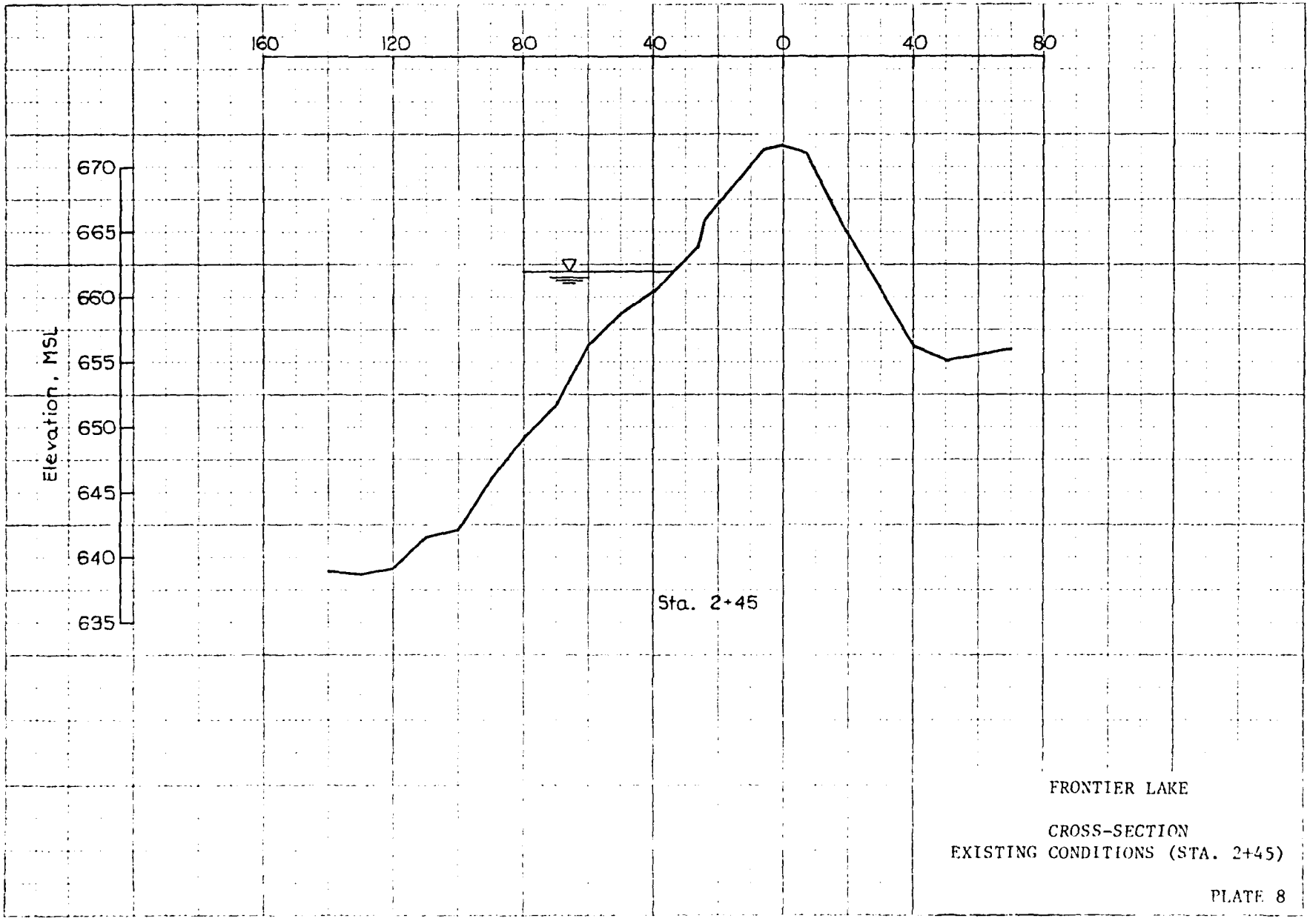
PLATE 6



FRONTIER LAKE

CROSS-SECTION
EXISTING CONDITIONS (STA. 1+63)

PLATE 7



FRONTIER LAKE

CROSS-SECTION
EXISTING CONDITIONS (STA. 2+45)

PLATE 8

PHOTO 1: Overview of Lake and Dam

PHOTO 2: Upstream Slope - Wave Wash

PHOTO 3: Downstream Slope - Brush and Small Trees

PHOTO 4: Inlet of Vertical Structure

PHOTO 5: Discharge of Vertical Structure

PHOTO 6: Emergency Spillway - Upstream View

PHOTO 7: Emergency Spillway Outfall - Spillway Guide Dike Erosion

PHOTO 8: Emergency Spillway - Upstream View (March 1977)

PHOTO 9: Emergency Spillway Outfall (March 1977)

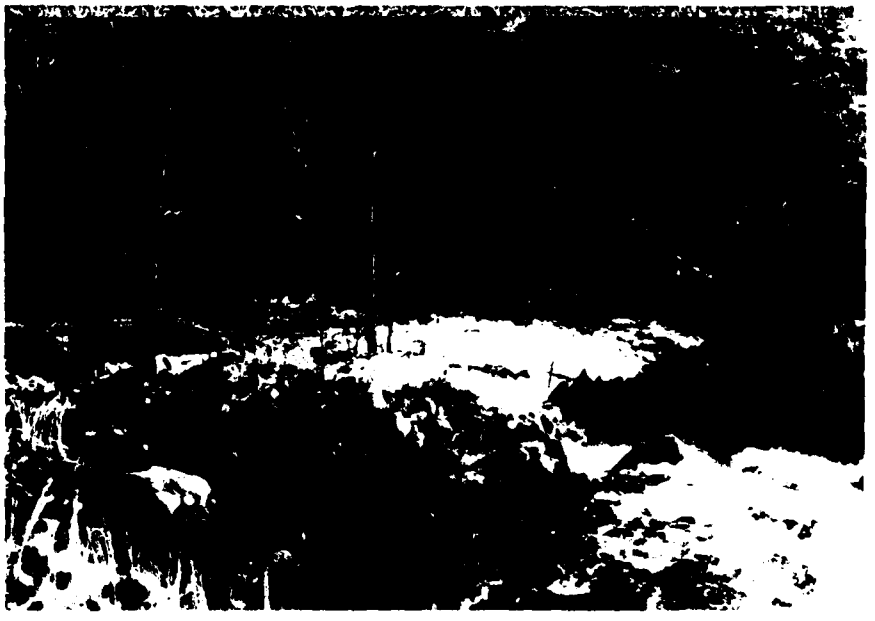


PHOTO 10: Emergency Spillway Outfall (March 1977)

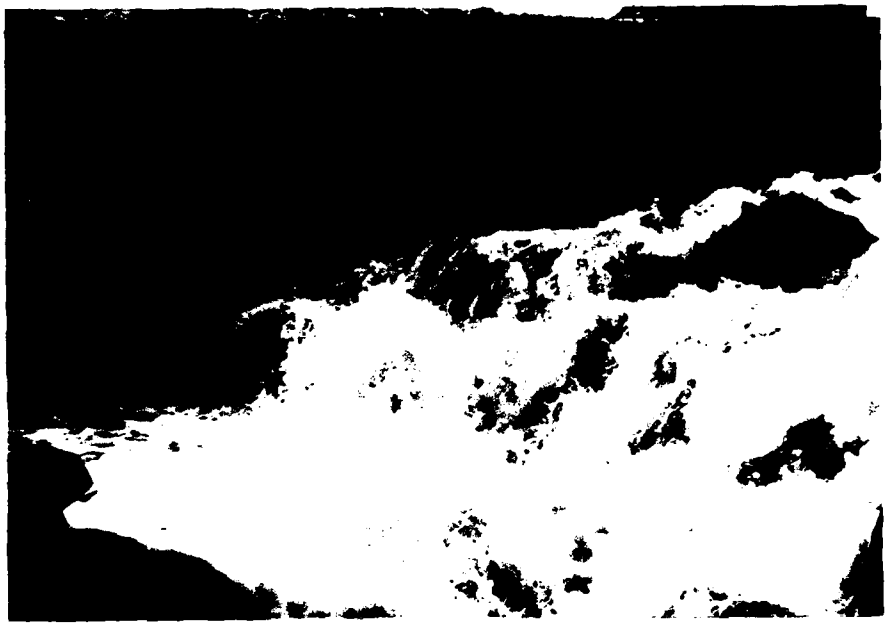


PHOTO 11: Emergency Spillway Outfall (March 1977)


DATE
ILME